MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

ERT3016 – ROBOTICS

(RE)

29 FEBRUARY 2020
2:30 p.m. - 4:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 6 pages including cover page with 5 Questions only. DH-parameter procedures are included in Appendix

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

a) Briefly explain the **THREE** safety zones in a work cell.

[6 marks]

b) SCARA (Selective Compliance Assembly Robot Arm) is one of the popular manipulators used in industry. Briefly discuss the unique features of this robot configuration.

[6 marks]

c) Robots are slowly finding their way into smart buildings, smart home, energy plants, hospitals, outer space, and more. Briefly discuss **TWO** examples of how robots could be used in non-industrial applications.

[8 marks]

Question 2

Let $F = \{f^1, f^2, f^3\}$ and $M = \{m^1, m^2, m^3\}$ be initially coincident fixed and mobile coordinate frames respectively. Suppose we perform a screw transformation along m^3 axis, rotating by $\pi/2$ radians and translating by a distance of $5cm$. Then, we perform another screw operation along m^1, rotating by $-\pi/2$ radians and translating by a distance of $8cm$. Let T_1 and T_2 denote the first and second screw transformation matrices respectively.

a) Show how the fixed coordinate frame is mapped to the mobile coordinate frame with a diagram.

[5 marks]

b) Determine the homogeneous transformation matrix, T_1

[3 marks]

c) Determine the homogeneous transformation matrix, T_2

[3 marks]

d) Given $[p]^M = [1, 2, 6]^T$, determine $[p]^F$.

[5 marks]

e) Explain how to reverse the transformations T_1 and T_2 in words.

[4 marks]

Continued .....

Question 3

Fig. Q3 is a 3-DOF manipulator. $J1$ is a revolute joint. Meanwhile, J2 and J3 are prismatic joints.

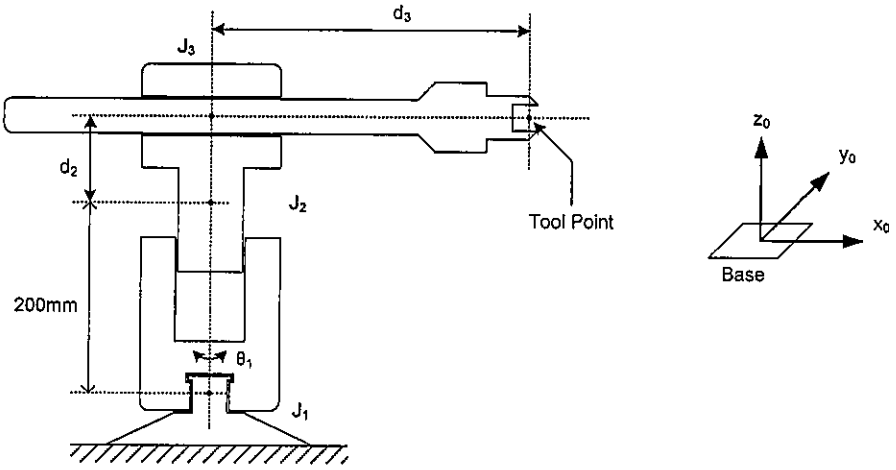

Fig. Q3

a) Using the base frame given in the figure, draw the link-coordinate diagram for the manipulator with all necessary kinematic parameters. (Refer to Table Q3 for its home position.)

[7 marks]

b) Complete the following table with its relevant kinematic parameters for the manipulator.

Table Q3

Axis	θ	d	a	α	Home
1					0
2	$\frac{\pi}{2}$				250mm
3	$\frac{\pi}{2}$				300mm

[5 marks]

c) Determine the arm matrix $T_{base}^{tool}(q)$ when the manipulator is set to the home position.

[8 marks]

Continued .....

Question 4

The following table shows the kinematics parameters of a 3-DOF robot, with R-R-P configuration.

Axis	θ	d	a	α
1	q_1	0	0	$\frac{\pi}{2}$
2	q_2	0	400	$\frac{\pi}{2}$
3	0	q_3	0	0

a) Determine the general arm equation, $T_0^3(q)$.

[12 marks]

b) Find the joint variables q_n, where $n = 1,2,3$. Given that the tool pose is:

$$T_0^3(q) = \begin{bmatrix} 0.433 & -0.5 & 0.75 & 323.2105 \\ -0.25 & -0.8660 & -0.433 & -186.6025 \\ 0.866 & 0 & -0.5 & 246.4102 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[8 marks]

Continued .....

Question 5

a) Consider the top view of a robotic workstation, with parts A and B, as shown in Fig. Q5. Suppose the centroid of part A has coordinates $[3, 10, 5]^T$ and the centroid of part B has coordinates $[8, 5, 4]^T$.

i. Find the arm matrix value T_{base}^{pick} needed to pick up part A from above by grasping it in the middle of the long sides.

[3 marks]

ii. Find the arm matrix value T_{base}^{pick} needed to pick up part B from above by grasping it in the middle of the long sides.

[4 marks]

iii. Find the arm matrix value T_{base}^{place} needed to place part B on top of part A aligning the centroids and the major axes.

[3 marks]

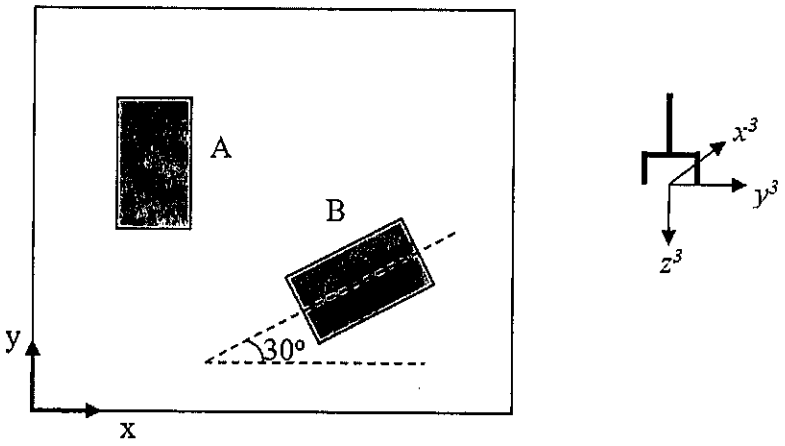

Fig. Q5

b) The waist of a six-axis robot is to go from initial angle of 20° to an end position of 74° in 6 seconds. By using a third-order polynomial in joint-space, calculate the joint angle, velocity, and acceleration at $time = 3\ seconds$. Assume the robot starts at rest and all joints stop at end point.

[10 marks]

Continued .....

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k=1$.
3. Align z^k with the axis of joint $k+1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set $k=1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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